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APPENDIX IV.

PARENT APPLICATION 09/218,067

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Ellen Peacock

APPLICATION FOR UNITED STATES LETTERS PATENT
FOR
WELLSITE CHEMICAL INJECTION AND MONITORING SYSTEM

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BACKGROUND OF THE INVENTION

1. Field of the Invention

5 This invention relates generally to oilfield operations and more particularly to a system for remotely monitoring and controlling apparatus that inject precise amounts of additives or chemicals into a wellbore or into wellbore fluid treatment or processing units at the wellsite.

2. Background of the Art

10 In production wells, chemicals (also referred to herein as "additives") are often injected from a surface source into the wells to treat the formation fluids flowing through such wells. A developed oil field may contain several oil wells. 15 Frequently between ten to thirty oil wells are drilled from a single offshore location.

 Frequently, one or more chemicals are injected into producing wells to, among other things, enhance production through the wellbore, or to control 20 hydrogen sulphide corrosion, scale, paraffin, emulsion and hydrates. Such chemicals are usually injected through a conduit or tubing that is run from the

surface to a known depth. Also, chemicals are introduced in connection with electrical submersible pumps (as shown for example in U.S. Patent No. 4,582,131 (assigned to the assignee hereof and incorporated herein by reference) or through an auxiliary line associated with a cable used with the electrical submersible pump (such as shown in U.S. Patent No. 5,528,824 assigned to the assignee hereof and incorporated herein by reference). Injection of chemicals into fluid treatment apparatus at the surface at the well site is also known.

Typically, a high pressure pump is used to inject a chemical from a source at the wellsite. The pump is usually operated continuously. The pump speed is set to control the amount of the injected fluid. Typically, a separate pump and an injector is used for each type of chemical for each well. Production wells are usually unmanned and many such wells are in very remote areas or on substantially unmanned offshore platforms. A recent survey of certain wellbores revealed that as many as thirty percent (30%) of chemical pumping systems at unmanned locations were either injecting incorrect amounts of the desired chemical or were totally inoperative. Incorrect chemical injection can lead to reduced production of hydrocarbons, clog the perforations or the various flow valves and other downhole equipment or increase the formation of corrosion scale, paraffins, emulsion and hydrates, thereby reducing the

effectiveness of the well and the operating life of the equipment in the wellbore, which can lead to very expensive rework operations, or in extreme situations, generation of dangerous levels of hydrogen sulphide and the abandonment of the wellbore.

5

Commercially used chemical injection apparatus usually require periodic manual inspection to determine whether the chemicals are correctly being dispensed. It is important for the industry to have chemical injection systems which can inject relatively precise amounts of chemicals, periodically or
10 continuously determine the precise amount of the chemical being dispensed and transmit operational the status of the injection system to a remote location so that appropriate action can be taken. The system should also include self-adjustment within defined parameters. Such a system should also be developed for monitoring and controlling chemical injection into multiple wells at a wellsite,
15 such as an offshore production platform. Manual intervention in the system to address other operational requirements at the wellsite should also be available.

The present invention addresses the above-noted problems associated with wellsite chemical injection systems and provides a system which dispenses
20 relatively precise amounts of chemical, determines the dispensed amount, takes certain corrective actions at the wellsite, communicates with a remote location,

takes

controls corrective actions locally, and/or receives commands from such remote locations and takes corrective actions in response to such commands.

SUMMARY OF THE INVENTION

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The present invention provides a system that monitors, at the wellsite, injection of additives into formation fluids recovered through wellbores and controls the supply of such additives, including with input from remote locations as appropriate. The system includes a pump that supplies under
10 pressure a selected additive from a source at the wellsite into the wellbore via a suitable supply line. A flow meter in the supply line measures the flow rate of the additive through the supply line and generates signals representative of the flow rate. A controller at the wellsite controls the pump to control the flow rate of the additive to the well and determines from the signals of the flow
15 meter the chemical flow rate and displays it on a display. The controller interfaces with a suitable two-way communication link and transmits signals and data representative of the flow rate to a second controller at a remote location. The remote controller may be a computer and may be used to transmit command signals to the wellsite controller representative of any
20 change desired for the flow rate. The wellsite controller adjusts the flow rate of the additive to the wellbore to achieve the desired level of chemical additives.

The wellsite controller is microprocessor based and may be programmed to adjust the flow rate automatically when the calculated flow rate is outside predetermined limits. The flow rate is increased when it falls below a lower limit and decreased when it exceeds an upper limit.

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The system of the present invention may be configured for multiple wells at a wellsite, such as an offshore platform. Such a system includes a separate pump, a fluid line and wellsite controller for each well. Alternatively, a suitable controller may be provided in communication with and in control of the pump for each well via separate connections or via a bus using addressable signaling. A separate flow meter provides signals representative of flow rate to the controller. The wellsite controller(s) may be programmed to display the flow rates in any order. The wellsite controller(s) transmit flow rate signals to the remote controller and adjust the flow rate to each well in response to the command signals received from the remote controller. The wellsite controller preferably periodically polls each flow meter and performs the above described functions. If a common additive is used for a number of wells, a common additive source may be used. A common pump may also be used with a separate control valve in each supply line that is controlled by the controller to adjust respective the flow rate.

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A suitable precision low flow, flow meter such as, for example, a nutating flow meter is used to make relatively precise measurements of the flow rate of the injected chemical. Any positive displacement type flow meter could also be used. The controller is environmentally sealed and can operate over a wide temperature range of temperatures. The present system is adapted to port to a variety of software and communications protocols and may be retrofitted on the commonly used manual systems.

The above described systems can also be used monitor the chemical injection into surface treatment units at the wellsite and to control the injection amounts from any remote location.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the preferred embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

Figure 1 is a schematic illustration of a chemical injection and monitoring system according to one embodiment of the present invention.

Figure 1A shows an alternative manner for controlling the operation of the high pressure pump.

Figure 1B shows a circuit for providing some measure of manual control of the controller for high pressure pump 22.

Figure 2 shows a functional diagram depicting one embodiment of the system for controlling and monitoring the injection of additives into multiple wellbores, utilizing a central controller on an addressable control bus.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 is a schematic diagram of a chemical injection system 10 according to one embodiment of the present invention. The system 10, in one aspect is shown, as injecting and monitoring the chemicals into a wellbore 50 and in another aspect injecting and monitoring chemicals into a surface treatment or processing unit 80. The wellbore 50 is shown to be a production well using typical completion equipment downhole. The wellbore 50 has a production zone 52 which has multiple perforations 54 through the formation 55. Formation fluid 56 enters a production pipe 60 in the well 50 via perforations 54 and passages 62. A screen 58 in the annulus 51 between the

production pipe 60 and the formation 55 prevents the flow of solids into the pipe 60 and also reduces the fluid velocity into the production pipe 60 to acceptable levels. An upper packer 64a above the perforations 54 and a lower packer 64b, in the annulus 51 respectively, isolate the production zone 52 from the annulus 51a above and annulus 51b below the production zone 52. A flow control valve 66 in the production pipe 60 can be used to control the fluid flow to the surface 12. A flow control valve 67 may be placed in the pipe 62 below the perforations to control fluid flow from any production zone below the production zone 52.

A smaller diameter tubing, such as tubing 68, may be used to carry the fluid from the production zones to the surface. A production well usually includes a casing 40 near the surface and a wellhead equipment 42. The wellhead equipment generally includes a blow-out prevention stack 44 and passages for supplying fluids into the wellbore. Valves (not shown) are provided to control fluid flow to the surface. Wellhead equipment and production well equipment, such as shown in the production well 60, are well known and thus are not described in greater detail.

As noted above, chemicals or additives are commonly injected in wellbores to control corrosion, scale, paraffins, emulsion and hydrates. A

variety of chemical injection systems are commercially available. The desired chemical is injected into the well via an injection tubing that runs from the surface to the desired wellbore depth. A pump supplies the chemical under pressure. A wellhead manifold is installed in the injection tubing at the surface to control pressure. One such system is commercially available from Baker Hughes Incorporated, the assignee of this application.

Referring back to Figure 1, in the present invention, the desired chemical 13 is injected into the wellbore 50 via an injection line 14 from a source 16 by a suitable high pressure pump such as a positive displacement pump 18. The chemical 13 flows through the line 14 and discharges into the production tubing 60 near the production zone 52 via inlets or passages ¹⁵~~18~~. The same or different injection lines may be used to supply chemicals to different production zones. In Figure 1, the line 14 is shown extending to the production zone below the zone 52.

Separate injection lines allow injection of different additives at different well depths. A suitable high-precision, low-flow, flow meter such as, for example, nutating flow meter 20, measures the flow rate through line 14 and provides signals representative of the fluid flow rate. The pump 18 is operated by a suitable device 22 such as a motor or other device. The stroke of the

The pump stroke

pump 18 defining fluid volume output per stroke, and/or the pump speed are controlled, e.g., by a 4 - 20 mA control signal, to control the output of the pump 18. ||

5 In the present invention, a controller 80 controls the operation of the pump 18, either utilizing programs stored in a memory 91 associated with the controller 80 or instructions provided to the controller 80 from a remote controller or processor 82. The controller 80 includes a microprocessor, resident memory both for storing the programs, such as read only memories
10 (ROM) and for storing data, such as in random access memories (RAM). The microprocessor, utilizing signals from the flow meter 20 and programs stored in the controller 80 determines the flow rate of the additive and displays such flow rate on the display 81. The controlled can be programmed to alter the pump speed (or rpm) and/or pump stroke to deliver the desired amount of the
15 chemical 13. The pump speed is increased if the measured amount of the chemical injected is less than the desired amount and decreased if the injected amount is greater than the desired amount. The controller 80 also includes circuits and programs, generally designated by numeral 91, to provide interface with the onsite display 81, interface with converter 83 and to perform other
20 desired functions.

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The controller **80** polls the flow meters provides chemical injection flow rate measurement signals to a suitable interface **83**, such as RS-485, which transmits the data to the remote controller **82**. The data may be transmitted via any suitable two-way data link. Such data links may include, among other things, telephone modems, radio frequency transmission, microwave transmission and satellites. The remote controller **82** is preferably a computer-based system and can transmit command signals to the controller **80** via the link **85**. The remote controller is provided with models/programs and can be operated manually and/or automatically to determine the desired amount of the additive to be injected. If the desired amount differs from the measured amount, it sends corresponding command signals to the wellsite controller **80**. The controller **80** receives the command signals and controls the flow rate of the chemical injection of the chemical **13** into the well **50** accordingly.

The controller **80** preferably includes protocols so that the flow meter **20**, pump control device **22**, and communication modules or links **83** made by a different manufacturers can be utilized in the system of this invention. In the oil industry, the analog output for pump control is typically configured for 0-5 VDC or 4-20 milliamps (mA) signal.

In one mode of the present invention, the controller **80** can be

programmed to provide such control. This allows for the system 10 to be used with existing pump controllers. A suitable source of electrical power, e.g., a solar-powered unit 89 or DC power, AC power, or on site generators (not shown) provides power to the controller 80, converter 83 and other circuit elements. The wellsite controller 80 is also provided with a display that displays the flow rates corresponding to the individual flow meters. This display may be scrolled by an operator so that any of the flow meters may be viewed. This display is controllable either by a signal from the remote controller or by a suitable interrogation device at the well site, such as an infrared device (not shown). This makes it possible for an operator at the wellsite to view the displayed data in the controller non-intrusively without taking apart the protective casing of the controller.

Still referring to Figure 1, the produced fluid 69 received at the surface is processed by a treatment unit or processing unit 75. The surface processing unit 75 may be of the type that processes the fluid 69 to remove solids and certain other materials such as hydrogen sulphide or that processes the fluid 69 to produce semi-refined to refined products. In such systems, it is desired to periodically or continuously inject certain chemicals. A system, such as system 10 shown in Figure 1 can be used for injecting and monitoring chemicals into the treatment unit 75.

In addition to the flow rate signals 21 from the flow meter 20, the controller 80 may be configured to receive signals representative of other parameters, such as the rpm of the pump 18, or the motor 22 or the modulating frequency of a solenoid valve. In one mode of operation, the controller 80 periodically polls the meter 20 and automatically adjusts the pump controller 22 via an analog input 22a or alternatively via a digital signal of a solenoid controlled system. The controller 80 also can be programmed to determine whether the pump output, as measured by the meter 20, corresponds to the level of signal 22a. This information can be used to determine the pump efficiency. It can also be an indication of a leak or another abnormality. Other sensors 94, such as vibration sensors, temperature sensors may be used to determine the physical condition of the pump 18. Sensors which determine the properties of the wellbore fluid can provide information of the treatment effectiveness of the chemical being injected , which information can then also be used to adjust the chemical flow rate.

Figure 1A shows an alternative manner for controlling the high pressure pump. This configuration includes a control valve, such as a solenoid valve 102, in the supply line 106 from a source of fluid under pressure (not shown) for the pump controller 22. The controller 80 controls the operation of the valve via suitable control signals, such as digital signals, provided to the valve

102 via line 104. The control of the valve 22 controls the speed or stroke of the pump 22 and thus the amount of the additive supplied to the wellbore 50. The valve 102 may be modulated to control the pump 18.

5 The automated modes of operation (both local and/or from remote location) of the injection system 10 are described above. In many cases, it is desirable to operate the control system 10 in a manual mode, such as by an operator at the wellsite. Manual control may be required to override the system because of malfunction of the system or to repair parts of the system 10.

10 **Figure 1B** shows a circuit for manual control of the high pressure pump 22. The circuit includes a switch 120 in the controller (see **Figure 1**), which in first or normal position allows the analog signal 22a from the controller to control the pump 22 and in the second position allows the manual circuit 124 to control the pump 22. The circuit in one embodiment may include a current control circuit,

15 such as a rheostat 126 that enables the operator to set the current at the desired value. In the preferred embodiment, the current range is set to between 4 and 20 ma, which is compatible with the current industry protocol. The remaining functions of the controller 80, such as the flow rate display, etc. continues to operate. Additionally, the controller is designed to interface with

20 manually remote devices, such as infrared devices. This allows the operator to communicate with and control the operation of the controller 80 while at the

well site, e.g., to calibrate the system, without disassembling the controller 80. This operator control includes resetting the allowable ranges for the flow rate and/or setting a value for the flow rate.

5 As noted above, it is common to drill several wellbores from the same location. For example, it is common to drill 10-20 wellbores from a single offshore location. After the wells are completed and producing, a separate pump and meter is installed to inject additives into each such wellbore. Figure 2 shows a functional diagram depicting one system 200 for controlling and
10 monitoring the injection of additives into multiple wellbores 202a-202m. In the configuration of Figure 2, a separate pump supplies an additive from a separate source to each of the wellbores 202a-202m. Pump 204a supplies an additive from the source 206a. Meter 208a measures the flow rate of the additive into the wellbore 202a and provides corresponding signals to a central controller
15 240. The controller in response to the flow meter signals and the programmed instructions or instructions from a remote controller 242 controls the operation of pump control device 210a via a bus using addressable signaling for each pump controller. Alternatively, the controller 80 may be connected to the pump controllers via a separate connection to each controller. Furthermore, a plurality
20 of wellsite controllers, one for each pump may be provided, with this plurality of controllers communicating with the remote controller via a bus or other

suitable connection. The controller also receives signal from sensors S1a associated with pump 204a via line 212a and from sensors S2a associated with pump controller 210a via line 212a. Such sensors may include rpm sensor, vibration sensor or any other sensor that provides information about a parameter of interest of such devices. Additives to the wells 202b-202m are respectively supplied by pumps 204b-204m from sources 206b-206m. Pump controller 210b-210m respectively control pumps 204b-204m while flow meters 208b-208m respectively measure flow rates to the wells 202b-202m. Lines 212b-212m and lines 214b-214m respectively communicate signal from S1b-S1m and S2b-S2m to the central controller 240. The controller 240 utilizes memory 246 for storing data and programs stored in memory 244 in the manner described above in reference to system 10 for controlling the pumps and for displaying information on the display 250. A suitable two-way link allows data and signals communication between the central controller 240 at the well site and the remote controller 242. The individual controllers would communicate with the sensors, pump controllers and remote controller via suitable corresponding connections.

The central controller 240 controls each pump independently. The controller can be programmed to compute the condition of each pump and the controller from the sensor signals. For example the controller can be

WHAT IS CLAIMED IS:

1 1. A system for monitoring at a wellsite supply of additives to
2 formation fluid recovered through a wellbore and controlling said supply from
3 a remote location, said system comprising:

4 (a) a flow control device controlling the flow rate of the supply of a
5 selected additive from a source thereof at the wellsite into said
6 formation fluid via a supply line;

7 (b) a flow measuring device measuring the flow rate of the additive
8 supplied to said formation fluid and generating signals indicative of
9 said flow rate;

10 (c) a first controller at the wellsite determining the flow rate of the
11 additive from the signals of the flow measuring device and
12 transmitting signals representative of the flow rate to the remote
13 location; and

14 (d) a second controller at said remote location receiving signals
15 transmitted by said first controller and in response thereto
16 transmitting command signals to said first controller representative
17 of a desired change in the flow rate of additive supplied;

18 wherein the first controller causes the flow control device to control the
19 flow rate of the supply of said additive in response to the command

signals.

1 2. The system of claim 1 wherein said first controller includes a display that
2 displays at least the flow rate of the additive supplied to the formation fluid.

1 3. The system of claim 1 wherein the additive is supplied to one of (a) a
2 location in the wellbore and (b) a hydrocarbon processing unit processing said
3 formation fluid at the wellsite.

1 4. The system of claim 1 wherein the flow measuring device is a positive
2 displacement flow meter.

1 5. The system of claim 1 wherein the flow measuring device is a nutating
2 flow meter.

1 6. The system of claim 1 wherein the first controller includes a manual
2 override circuit that enables an operator to manually control the operation
3 of the flow control device and thus the flow rate of the additive.

1 7. The system of claim 1 wherein the first controller includes a
2 microprocessor and programmed instructions for use by the

3 microprocessor to compute the flow rate.

1 8. The system of claim 1 wherein the flow control device includes a high
2 pressure pump.

1 9. The system of claim 8 further including a solenoid valve that controls the
2 operation of said high pressure pump.

1 10. The system of claim 9 wherein said first controller controls the solenoid
2 pump.

1 11. The system of claim 1 wherein the second controller is a computer.

1 12. A system for monitoring at a wellsite supply of additives to a plurality of
2 wells at a common wellsite and controlling said supply from a remote
3 location, said system comprising:

4 (a) a flow control device controlling the flow rate of supply of a
5 selected additive from a source thereof at the wellsite into each of
6 said plurality of wells via a separate supply line;

7 (b) a flow measuring device in each said supply line measuring the
8 flow rate of the additive supplied to a corresponding well, each

said flow measuring device generating signals indicative of a flow rate of the additive to its corresponding well;

- (c) a first controller at the wellsite determining the flow rate of the additive to each well from the signals of the flow measuring device associated with such well and transmitting signals representative of the flow rate for each well to a remote location; and
- (d) a second remote controller at said remote location receiving signals transmitted by said first controller and in response thereto transmitting to said first controller command signals representative of a desired change in the flow rate of additive supplied each said well;

wherein the first controller causes the flow control device to control the supply of additives to each well in response to the district command signals corresponding to said well.

13. The system of claim 12 wherein the additive is supplied to one of (a) a location in one or more e of the plurality of wellbore and (b) a hydrocarbon processing unit processing said formation fluid at the wellsite.

14. The system of claim 12 wherein the flow measuring device in at least

2 one of supply lines is a positive displacement flow meter.

1 15. The system of claim 12 wherein the flow measuring device in at least
2 one of supply lines is a nutating flow meter.

1 16. The system of claim 12 wherein the first controller includes a manual
2 override circuit that enables an operator to manually control the flow rate
3 of the additive.

1 17. The system of claim 12 wherein the flow control device includes a high
2 pressure pump.

1 18. The system of claim 17 further including a solenoid valve that controls
2 the operation of said high pressure pump.

1 19. A method of monitoring at a wellsite supply of additives to formation
2 fluid recovered through a wellbore and controlling said supply from a
3 remote location, said system comprising:

4 (a) controlling the flow rate of the supply of a selected additive from
5 a source thereof at the wellsite into said formation fluid via a
6 supply line;

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- (
- 7 (b) measuring with a flow measuring device measuring the flow rate
8 of the additive supplied to said formation fluid and generating a
9 signal indicative of said flow rate;
10 (c) determining at the wellsite the flow rate of the additive from the
11 signal of the flow measuring device and transmitting a signal
12 representative of the flow rate to the remote location; and
13 (d) receiving at said remote location signals transmitted from the
14 wellsite and in response thereto transmitting command signals to
15 the wellsite representative of a desired change in the flow rate of
16 additive supplied; and
17 (e) controlling the flow rate of the supply of said additive in response
18 to the command signals

1 20. The method of claim 19 further comprising displaying at the well site the
2 flow rate of the additive supplied to the formation fluid.

1 21. The method of claim 19 further comprising providing a manual override
2 to override the remote control of the flow rate of the additive.

1 22. The method of claim 19 wherein providing a manual override further
2 comprises an operation selected from (i) setting a flow rate of the

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additive, and (ii) setting a range of allowable values for the flow rate of the additive.

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ABSTRACT

1 A system that monitors at the wellsite injection of additives into
2 formation fluids recovered through wellbores controls the supply of such
3 additives from remote locations. A pump supplies under pressure a selected
4 additive from a source at the wellsite into the wellbore via a suitable supply line.
5 A flow meter in the supply line measures the flow rate of the additive through
6 the supply line and generates signals representative of the flow rate. A
7 controller at the wellsite controls the pump to control the flow rate of the
8 additive to the well and determines from the flow meter signals the flow rate.
9 The controller interfaces with a suitable two-way communication link and
10 transmits signals and data representative of the flow rate to a second controller
11 at a remote location. The remote controller transmits command signals to the
12 wellsite controller representative of any change desired for the flow rate. The
13 wellsite controller adjusts the pump speed to alter the flow rate of the additive
14 to the wellbore. The wellsite controller is microprocessor based and may be
15 programmed to adjust the flow rate automatically when the calculated flow rate
16 is outside predetermined limits. The flow rate is increased when it falls below
17 a lower limit and decreased when it exceeds and upper limit. The system of the
18 present invention may be configured for multiple wells at a wellsite, such as an
19 offshore platform.

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programmed to determine the vibration and rpm of each such device. This can provide information about the effectiveness of each such pump and the controller. The controller can be programmed to poll the flow rate and the parameters of interest of each pump and the pump controller periodically and
5 the perform the desired computations at the well site and then transmit the results to the remote controller 242 via the telemetry interface 248. The remote controller 242 may be programmed to determine any course of action from the received information and any other information available to it and transmit corresponding command signals to the wellsite central controller 240.
10 Again, communication with a plurality of individual controllers would be done in a suitable corresponding manner.

While foregoing disclosure is directed to the preferred embodiments of the invention, various modifications will be apparent to those skilled in the art.
15 It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

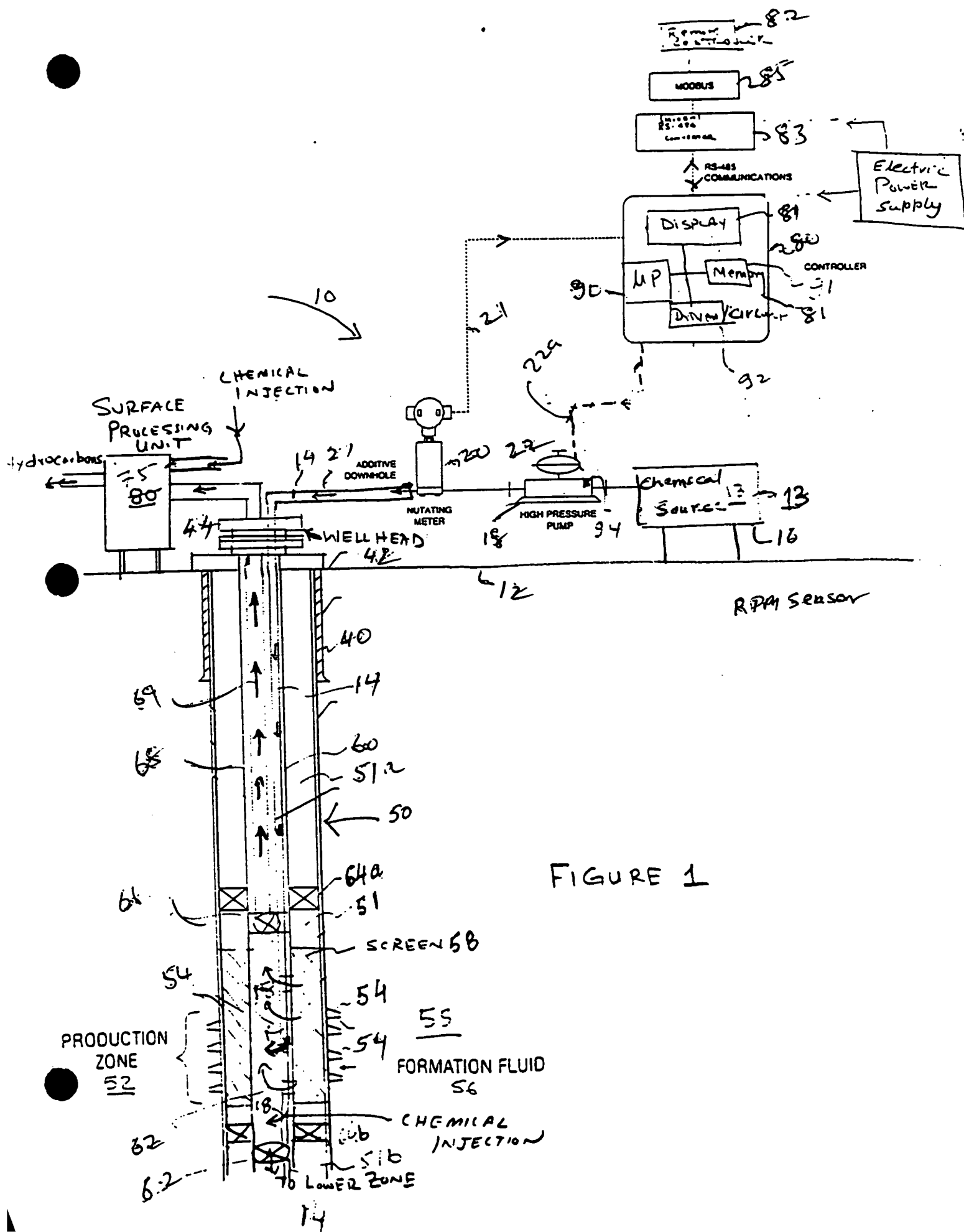


FIGURE 1

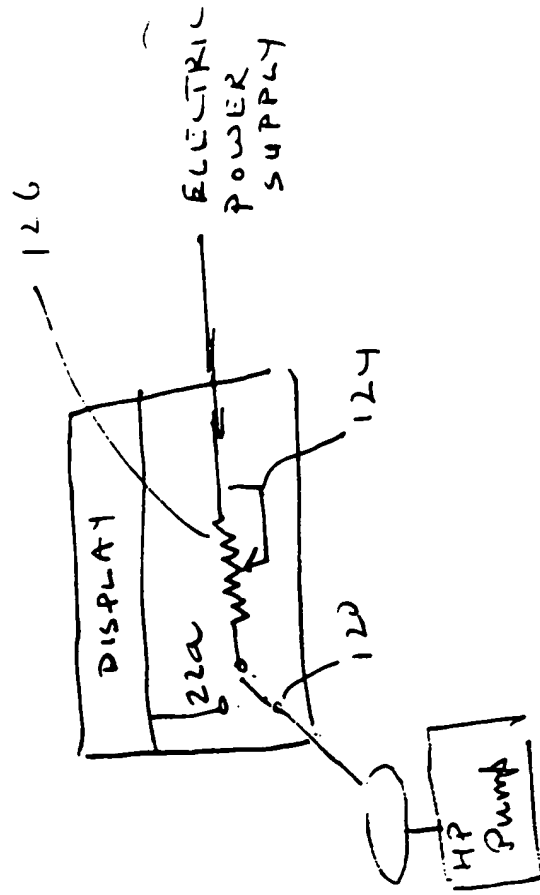


FIG. 1B

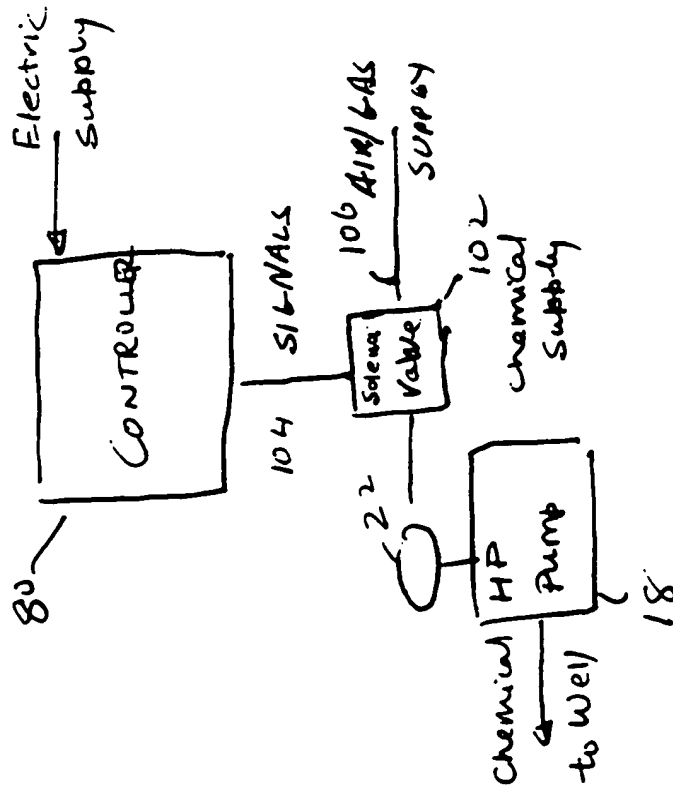


FIG. 1A

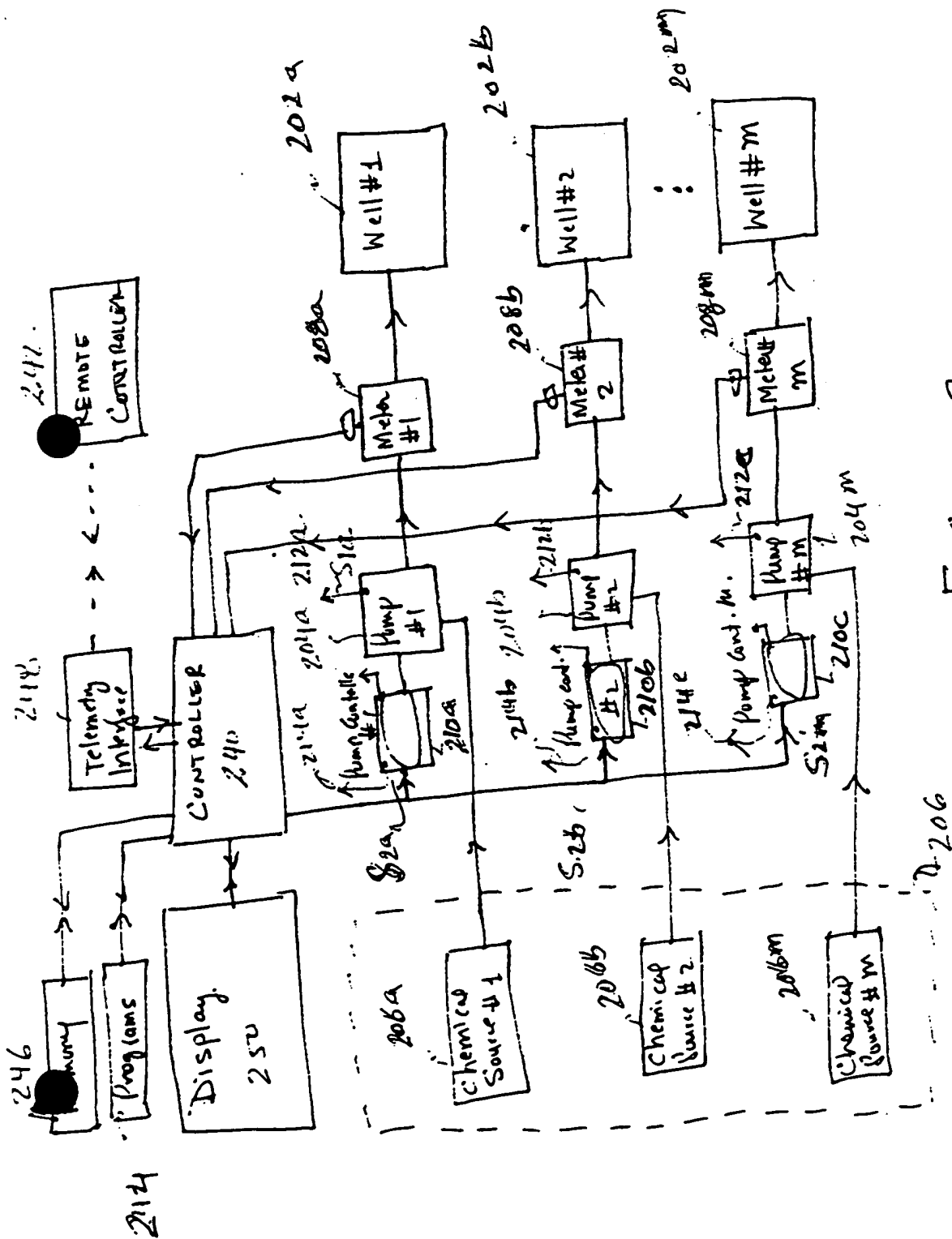


FIGURE 2.